Geophysical Research Abstracts, Vol. 7, 05788, 2005
SRef-ID: 1607-7962/gra/EGU05-A-05788

Exploring nonlinear mechanical behaviour in rocks at LANSCE

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Neutron scattering offers an unprecedented capability to explore the bulk internal strain and compositional state of materials. In particular, consolidated rocks may be studied using volumes that are large enough to usefully average over local inhomogeneities and thus provide results which may be compared to rocks in the Earth's mantle and crust. It has long been known from both quasistatic and dynamic tests that most rocks display significant nonlinear mechanical behaviours, such as non-Hooke's law elasticity and hysteresis, and that these behaviours are strongly affected by environmental parameters like temperature, moisture content and strain. Despite this knowledge, and a number of phenomenological models which reproduce these behaviours qualitatively, there is still no consensus on the physical processes responsible for the nonlinearities, nor even if the same effects are active in all rocks which display them. We have carried out experiments at three neutron beamlines in the Lujan facility at the Los Alamos Neutron Science Center (LANSCE) to explore the composition, strain response and rate/temperature dependence of quartz sandstones (which display large nonlinear effects) to focus on the microscopic physical processes active in nonlinear responses. We performed uniaxial quasistatic strain measurements at the SMARTS beamline which is equipped with an hydraulic press for simultaneous neutron diffraction and macroscopic stress-strain measurements. The difference between the average crystal lattice strain and the applied strain leads us to conclude that a tiny fraction of the material near the grain contacts is responsible for the extraordinary macroscopic response[1]. Structural/compositional information is gathered on the NPDF beamline and pair distribution function (PDF) analysis has been applied to demonstrate that an unexpectedly large fraction of the quartz may be amorphous. We present the hypothesis that this material may be concentrated at the bonded contacts

between grains[2]. The high intensity/count rate HIPPO beamline is used to explore the dynamical modulus response of consolidated samples with temperature changes. An ultrasonic resonance method monitors the average modulus change while neutron diffraction simultaneously records the average lattice strains. Preliminary results indicate that the crystal lattice in the grains responds essentially instantaneously to the temperature change while the elastic modulus of the rock responds with a much slower time constant. We will present these results and our thoughts for future experiments. This work is supported by internal LDRD funding at the Los Alamos National Laboratory.

References:

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